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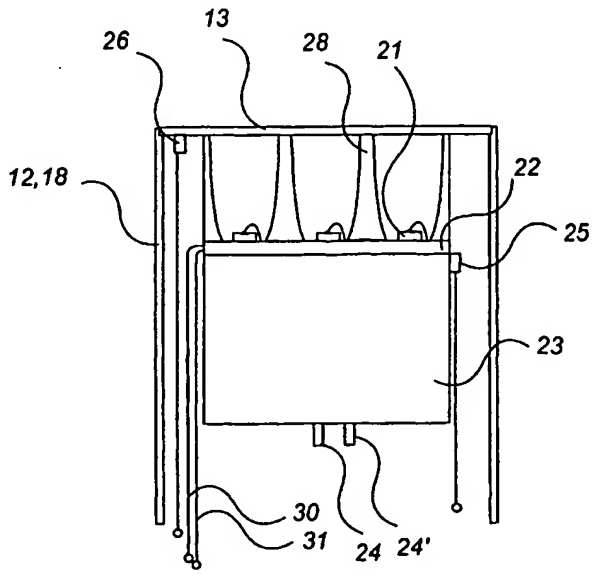
Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: LIGHT CURER AND METHOD FOR CURING SUBSTANCES WITH LIGHT



(57) Abstract: The invention relates to a light curer and a method for curing substances with light. The light curer contains a hand-piece and a tip, from where light emitted from at least two light emitting diodes (LED) is lead to the substance to be cured. The light from the LEDs is gathered and directed towards the object by a reflector matrix.

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LIGHT CURER AND METHOD FOR CURING SUBSTANCES WITH LIGHT

This invention relates to a light curer according to the preamble of claim 1, which includes a light source and a handpiece or the like including or being connectable to a power source, the handpiece having a fixed or a removable tip part from where the light can be led through an opening, window or the like permeable to the curing radiation to the object to be cured. The invention also relates to a method according to the preamble of claim 20, according to which the material to be cured is illuminated using a led curer including a light source and a handpiece or the like including or being connectable to a power source, the handpiece having a fixed or a removable tip part from where the light is led through an opening, window or the like permeable to the curing radiation to the object to be cured.

Traditionally various metallic materials or materials containing metal have been used to repair cavities of teeth. Since the potential health risks of especially amalgam have been realized, of the substitute materials widely popular have become the light curable polymers, which typically contain at least some monomer and some light sensitive material catalysing the polymerisation reaction of the monomers.

The absorption spectrum of the light sensitive materials is usually quite narrow, typically much narrower than that of the incandescent and halogen lamps generally used as a light source in light curers. When the light source has a wide emission spectrum its efficiency in view of producing radiation relevant to curing is quite low already to begin with. Further, an additional problem in this kind of light sources is weakening of the intensity caused by aging and possible damages, which naturally is a risk in view of successful curing of the material to be polymerised, and also the thermal radiation, which can cause alterations in the shape and volume in the material to be cured. The problems caused by thermal radiation are not necessarily overcome even with the help of radiation filters, which are usually at least partially permeable to thermal radiation, too. The devices based on such a technology are also unpractical as far as their design is concerned and cannot be constructed identical with the other instruments used in dental work because of the great space requirements of the light source and reflector structures. Then also placing them e.g. on the instrument table of a dental unit is somewhat difficult.

These kind of devices have been presented e.g. in the US patent publication 4,298,806 and in the published DE patent application 34 11 996.

In order to be able to utilize the electrical energy used for production of light for generation of especially the effective wave lengths, the development of such light curing devices has begun that have as their light source components including various semiconductor elements, such as light emitting diodes, or LEDs. Typically both in such and also in the solutions as described above utilising lamps, the radiation got from the light source or sources is led into a light conductor, like an optical fiber, and through it further to the object to be cured. Devices containing such LED groups have been presented e.g. in the DE patent publication 199 43 393 and in the WO publication 00/13608.

Even though the use of LEDs improves as the starting point the efficiency of a light curing device, there are always problems of their own in the solutions where light conductors are used. For example, in the device according to the figures of the DE publication mentioned above, all the light produced by the LEDs cannot be directed to the object to be cured since only the rays that enter the light conductor at an angle smaller than a specific limit angle will begin to travel in the fiber, while the rays that enter at a greater angle will escape out of the fiber. Also on the whole the light transmission capability of this kind of fibers, which break and crack easily, is about 60-80% even when undamaged.

On the other hand, when light is led from the light diodes to the object to be cured via lenses as in the prior art, each semiconductor element becomes imaged on the surface of the material to be cured, thus forming onto it spot-like intensity concentrations.

Representatives of the prior art technology are also solutions presented in the US patent publication 5,420,768 and e.g. in the WO publication 97/36552, where LEDs have been arranged to form a matrix or an equivalent. Large structures constituting even of hundreds of diodes are suggested by the publication, where optically converging means would be used to direct the light to the object to be cured.

In view of losses of light intensity it would obviously be natural to place the light source as close to the object to be cured as possible. Hence, e.g. the US

patent publication 6,159,005 teaches that a light source being favourably made up of laser diodes may be placed essentially in the tip of a light curing device. There is not presented any specific suggestion for details of such a construction in the publication. A corresponding basic solution is discussed also in the US patent publication 5,634,711, where semiconductor means emitting light are proposed to be placed in the point of a tip part, the tip part possibly including a joint or equivalent, in order to be able to replace an optical fibre with an optical "cork", such as a TIR lens which will collimate the light received from the LEDs.

There has been referred to the possibility of arranging LEDs to form a kind of "irradiation tip" also in the WO publication 00/13608 mentioned above, in which tip some lens gathering the emission light would be used.

Thus, a problem in those light curer solutions where the LEDs are arranged in the tip of the light curer is that, when a lens or a lens matrix is used, the intensity of the light will be uneven because of an image of the light source will be formed on the object to be cured and, on the other hand, when lenses are not used, the efficiency of the scattered light bundle may be insufficient especially in deeper layers of the material to be cured.

Yet as a further representative of the prior art the EP publication 1 090 607 can be mentioned, where it has been presented placing LEDs in holes, possibly made of light reflecting material, and arranging a lens matrix on top of such a construction, and further yet the US patent publication 5,463,711, where there has been arranged reflectors beneath individual LEDs to gather light, which will subsequently be led to the object via a converging optical fibre.

The object of the present invention is to get rid of the defects presented above specifically in order to reach a simple construction for light curers, the intensity of the wave lengths in the object relevant to curing produced by them, however, being at least of the same order of magnitude as in the prior solutions.

On the other hand, an object of the invention is to improve uniformity of the density of light that will be led to the material to cured in comparison with many of the prior art LED curers.

A further object of the invention is to provide an opportunity for designing light curers that may be more practically fit in the instrument holders of dental units, and the design of which will resemble that of other dental instruments.

Essentially these objectives will be reached with the solutions defined in the claims below, especially with the ones defined in the characterising parts of the independent claims. When a light source of a light curer is arranged to be formed of a construction comprising at least two light emitting diodes, which emit one or several specific wave lengths, and preferably on top of which has been arranged a reflector matrix that will gather light and direct light beams towards the object to be cured, and further if the light diodes are placed in an essential vicinity of an opening, or a window permeable to light, arranged in the tip part of the light curer, one is able to achieve a sufficient intensity with a relative small amount of light diodes without lenses that would require precise manufacture and assembly and without fibre optics that are expensive and cause losses of intensity.

In the following, the invention and its characteristic features will be described in more detail by referring to some of its preferable embodiments and the attached drawings. The invention is not meant to be limited to these embodiments only, however, and the essential features of it are precisely presented in the attached claims, especially in the characterizing parts of the independent claims. Of the attached Figures

Figs. 1a and 1b present a basic structure of a light curing device according to the invention,

Fig. 2 presents a structure of a light source applicable to be used in a light curing device according to the invention and

Fig. 3 presents another construction of a light source applicable to be used in a light curer according to the invention.

In Figs. 1a and 1b there is presented a light curing device (10), which includes a hand piece (11) and a tip part (12) in connection with it. A light source (14) is placed inside the tip part (12) in the essential vicinity of an opening or a window (13) arranged in it. The light curing device (10) according to Figs. 1a and 1b includes a separate, loadable and/or replaceable power source (15) or

means (15') for connecting it to a separate power source, like a dental unit. The structure further includes control means (16) for controlling the operation parameters, like diode current and/or cooling efficiency of the device. In the tip part (12) of the light curing device (10) according to Fig. 1a there is further arranged a special tumable, e.g. a jointed (17) part (18), which enables placing the light source (14) as near to the object to be cured as possible.

Fig. 2 presents a light source structure suitable to be used in a light curing device according to the invention, where light emitting diodes (21) emitting one particular wave length or several particular wave lengths are placed in the essential vicinity of an opening or a window (13) being situated in the tip part (12, 18) of the light curing device, the opposite surfaces of the diodes being connected straight to the hybrid (22), or PCB. In the solution according to Fig. 2, the hybrid (22) is connected to a cooling element (23) equipped preferably with cooling channels and connections (24, 24') for the media used for cooling. The structure according to Fig. 2 also includes means (25, 26) for measuring the temperature of the substrate and the intensity of light, and a reflector matrix (28) substantially gathering the light emitted from the light diodes and also substantially directing it towards the object to be cured. The reflector matrix (28) consists preferably of a uniform piece, which is easy to position on top of the LEDs. The surfaces of the reflector matrix (28) may be ellipses or other aspheric surfaces, or concave structures containing even plane surfaces that imitate such surfaces. It is preferable to place the LEDs (21) in the led curer in a way that they themselves, or the tailing edges of the reflector matrix (28) in view of the direction of travel of light, are situated in the essential vicinity of the opening or the window (13) of the tip part (12, 18) of the curer. In the figure there are additionally presented the electric connectors (30, 31) needed for creating a voltage across the LEDs (21).

Typically the dimension of individual reflector surfaces of the reflector matrix (28) according to the invention in the direction which the light travels is at least the same, preferably multiple compared to that of the perpendicular dimension of the individual light diodes (21) – but also compared to such perpendicular dimension of individual reflector surfaces. Individual reflector surfaces may gather light from one or several light emitting diodes. Such a reflector matrix (28) or its base may be made, among other things, by machining, casting or by the so-called LIGA-technique, but in principle also for example by growing it on the same silicon substrate together with the LEDs.

The light source according to Fig. 2 may consist not only of a structure formed of light diodes (21), especially of ones not put in cases, which are fixed and connected straight to a ceramic hybrid (22), but also of a single semiconductor structure which has several light emitting diodes, or of several semiconductor structures each of which having one or more light emitting diodes. Such a light emitting surface, to be presented in more detail below, may consist of e.g. one or more pieces of semiconductor material fixed to e.g. a cooling element or some other surface, i.e. of a structure with no hybrid, on which semiconductor surface or surfaces there has been arranged several light diodes.

Departing from what has been presented in Fig. 2, the other connecting surfaces of the light diodes (21) may alternatively be connected straight to the cooling element (23), e.g. by arranging holes to the hybrid (22) and placing the light diodes (21) on the bottom of these holes. On the other hand, according to yet another embodiment of the invention, the hybrid (22) may be totally omitted by arranging on the surface of the cooling element (23), or on the surfaces of the reflector matrix (28), insulated electric connectors connected to at least the other connection surfaces of the light diodes (21).

Yet another preferable embodiment of the invention has been presented in Fig. 3, where the electric contacts of the LEDs have been connected to common potentials, through contact surfaces (29) arranged on the reflector matrix (28) on one hand, and to the cooling element (23) on the other. In such a solution, where there naturally has to be arranged a proper insulation between the electricity conducting cooling element (23), which may be e.g. copper, and the reflector matrix (28), which may be e.g. aluminium, there is thus not needed at all a hybrid (22) according to Fig. 2. Even though some possibilities are lost for sophisticated applications for the light curer by using such a parallel connection, a very simple and thus economical-to-manufacture construction is thus reached, however. Also in more general terms the invention makes possible such a compact structure, in view of its physical dimensions, in which the light source is placed in the tip of an instrument and which has such a shape common in dental instruments that has been found to be ergonomically favourable.

In different embodiments of the invention, on the light emitting surface there may thus be arranged diodes emitting more than one specific wavelength. On the other hand, in some embodiments of the invention the electronics of the

light source may be arranged to form light diode groups connected in series and the connections may also be realized in a way that spatial switching on and off of the diodes may be carried out in a sequence. The light diode groups may be arranged to form e.g. concentric circles, and means for measuring temperature of the hybrid and/or intensity of the light emitted by the light curer may be utilized in controlling the light curer by adjusting e.g. the flow of the cooling agent and/or the diode current based on the measurement signals received from these means. Such preferable embodiments of the invention allow for wide possibilities to control and adjust operation of the device and thus control the curing process. The curing process may be initiated e.g. from the centre of the curable material, if desired, whereby the odds for typical failures in the curing process, such as formation of cracks as well as formation of notches into the edge regions of the curable material can be reduced. The intensity of light produced by the light source can be adjusted, especially it can be held stable during the whole operational life of the light diodes, and the device can be protected from overheating by arranging in it means for cutting off the power when the temperature measurement signal reaches its safety limit value.

The light curer according to the invention can be realized both as a device functioning independently and by connecting it to a dental unit, in which case the cooling media, such as compressed air, can be led from the dental unit to a cooling element made e.g. of material of high thermal conductivity, such as metal. The cooling element is e.g. in its cross section essentially uniform with the substrate, in which case they together may form in its cross section e.g. a polygonal, such as an octagonal structure, which can be fixed by its corners to the tip part of the light curing device. The light curer can be arranged to be connectable to an instrument site or straight to the instrument hose of a dental unit, especially to a so called multiflex quick connector, preferably to a connector which recognizes the instrument or the instrument type.

The window possibly used in the tip part of the light curer can be e.g. a sapphire window whereto it is advantageous to arrange a covering which removes reflection.

In the above, a few preferable embodiments of the invention at hand have been presented in quite a compressed way, to which the invention is not meant to be solely limited, though. The essential features of the invention are

defined in the attached claims, within which several different embodiments are possible.

CLAIMS

1. Light curer for curing substances used especially in methods of dentistry, which device includes a light source (14) and a handpiece (11) or the like including or being connectable to a power source (15), which handpiece (11) is connected to a fixed or a removable tip part (12, 18), from where the light may be led to the object to be cured through an opening, a window or the like (13) permeable to light, and where means for gathering light emitted by the light source (14) have been arranged in the vicinity of the light source (14), characterized in that the light source (14) includes at least two light diodes (21) emitting one particular or several particular wavelengths arranged in operational connection with a reflector matrix (28) gathering light from the said at least two light diodes (21).

2. Light curer according to claim 1, characterized in that the said reflector matrix (28) includes surfaces extending around the light diodes (21) that gather light and direct light beams towards the object to be cured.

3. Light curer according to claim 2, characterized in that the said surfaces are ellipses or other aspheric surfaces.

4. Light curer according to any of claims 1-3, characterized in that the light source (14), or at least the tailing edge of the reflector matrix (28) substantially in connection with it, is placed in the essential vicinity of the said opening or the window (13).

5. Light curer according to any of claims 1-4, characterized in that a cooling element (23) is arranged in the essential vicinity of the light diodes (21).

6. Light curer according to any of claims 1-5, characterized in that at least one of the electric contact surfaces of the light diodes (21) are connected to a hybrid (22) or a PCB arranged below the reflector matrix (28).

7. Light curer according to any of claims 1-6, characterized in that at least one of the electric contact surfaces of the light diodes (21) are connected to electric conductors (29) arranged e.g. on the surfaces of the cooling element (23) or the reflector matrix (28).

8. Light curer according to any of claims 5-7, characterized in that one of the electric contact surfaces of the light diodes (21) are connected to a cooling element (23) of electricity conducting material, such as copper (Cu).

9. Light curer according to any of claims 1-8, characterized in that one of the electric contact surfaces of the light diodes (21) are connected to a reflector matrix (28) of electricity conducting material, such as aluminium (Al).

10. Light curer according to any of claims 1-9, characterized in that the electric contact surfaces by which a voltage is connected across the light diodes (21) are arranged on the opposite surfaces of the light diodes (21).

11. Light curer according to any of claims 1-10, characterized in that the electric connections of the light diodes (21) are realized in a way which enables their spatial switching on and off in a sequence.

12. Light curer according to one of the claims 1-11, characterized in that at least part of the electric connections of the light diodes (21) are realized to form light diode groups connected in series.

13. Light curer according to any of the claims 1-12, characterized in that the light diodes (21) or the said light diode groups are arranged to form concentric circles.

14. Light curer according to any of the claims 6-13, characterized in that the said cooling element (23) is of its cross-section essentially uniform with e.g. the said hybrid (22), which thus together form of its cross-section a polygonal, such as an octagonal structure, that is fixed to said tip part (12, 18) by its corners.

15. Light curer according to any of the claims 1-14, characterized in that the light curer (10) includes means for connecting it to a dental unit, especially to an instrument site or an instrument hose of a dental unit, especially to a so called multiflex quick connector, preferably to a connector that recognizes an instrument or an instrument type.

16. Light curer according to claim 15, characterized in that the said means for connecting the light curer (10) to a dental unit include means for

leading cooling agent, such as compressed air, from the dental unit to the cooling channels (24) of the said cooling element (23).

17. Light curer according to any of the claims 1-16, characterized in that there are arranged means (25, 26) for measuring e.g. temperature of the said substrate (22) and/or intensity of the light produced by the light curer (10) and means for controlling operation of the light curer (10) based on such a measurement signal or signals, like means for adjusting flow of the said cooling agent and/or diode current, especially for holding the intensity stable and/or for cutting off the power when the said temperature measurement signal reaches its safety limit value.

18. Light curer according to any of the claims 1-17, characterized in that the said opening (13) in the tip part of the light curer (10) and the said light source (14) are placed in a turnable part (18) in the head of the said tip part (12).

19. Light curer according to any of the claims 1-17, characterized in that the light curer (10) has been constructed to be essentially of the same shape as the other typical dental instruments.

20. Method for curing substances with light, especially for curing substances used in methods of dentistry, in which method the material to be cured is illuminated with a light curer that has a light source and a power source in it or which is connectable to a power source, which light curer includes a handpiece or the like, which handpiece is connected to a fixed or a removable tip part, from which light is led via reflecting means and an opening, a window or the like to the object to be cured, characterized in that the light which is produced with at least two light emitting diodes emitting one particular wave length or several particular wave lengths is gathered with a reflector matrix to be led to the object to be cured through the said opening or window.

21. Method according to claim 20, characterized in that the light is gathered and led towards the object to be cured in the reflector matrix.

22. Method according to claim 20 or 21, characterized in that the light diodes are arranged in electric connection with at least the hybrid that is arranged beneath the reflector matrix.

23. Method according to any of the claims 20-22, characterized in that the light diodes are arranged to be in electric connection with the electric connectors arranged at least on some surface beneath the reflector matrix or on the surfaces of the reflector matrix.

24. Method according to any of the claims 20-23, characterized in that the light diodes are arranged in the second electric connection with the cooling element of electricity conducting material arranged in the curer.

25. Method according to any of the claims 20-24, characterized in that the light diodes are arranged in the second electric connection with the reflector matrix of electricity conducting material arranged in the curer.

26. Method according to any of the claims 22-25, characterized in that voltage is connected across the light diodes from their opposite surfaces.

27. Method according to any of the claims 20-26, characterized in that the spatial switching on and off of the light diodes is realized in sequence.

28. Method according to any of the claims 20-27, characterized in that the light curer is connected to a dental unit, especially to an instrument site or an instrument hose of a dental unit, especially to a so called multiflex quick connector, preferably to a connector that recognizes an instrument or an instrument type, and the electric current needed for operating the light source, and the possibly needed cooling agent, such as compressed air, are led to it from the dental unit.

29. Method according to any of the claims 20-28, characterized in that operation of the light curer, e.g. temperature of the said substrate and/or intensity of the light produced by the light curer, is measured and operation of the light curer is controlled based on such a measurement signal or signals, especially for holding the intensity of the light produced by the light curer stable and/or for cutting off the power when the said temperature measurement signal reaches its safety limit value.

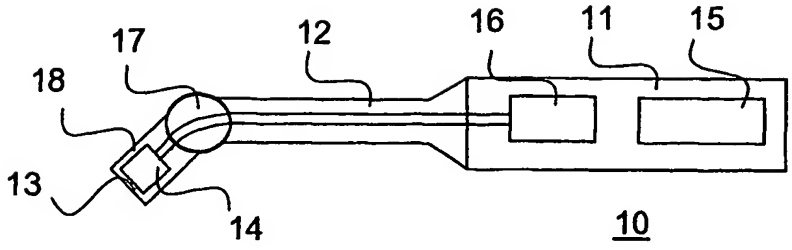

FIG. 1 a

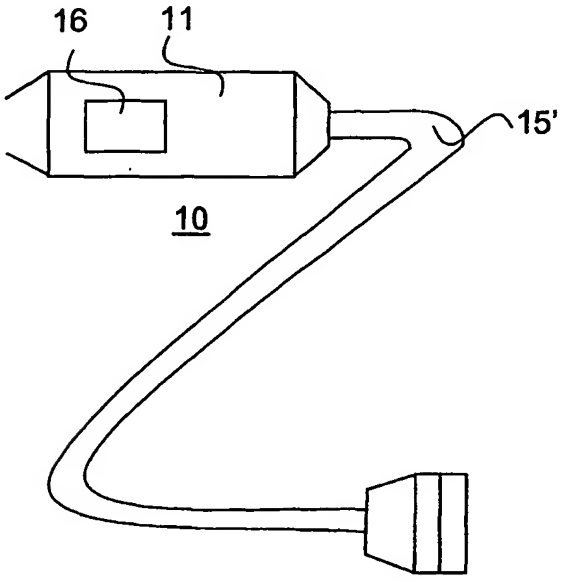

FIG. 1 b

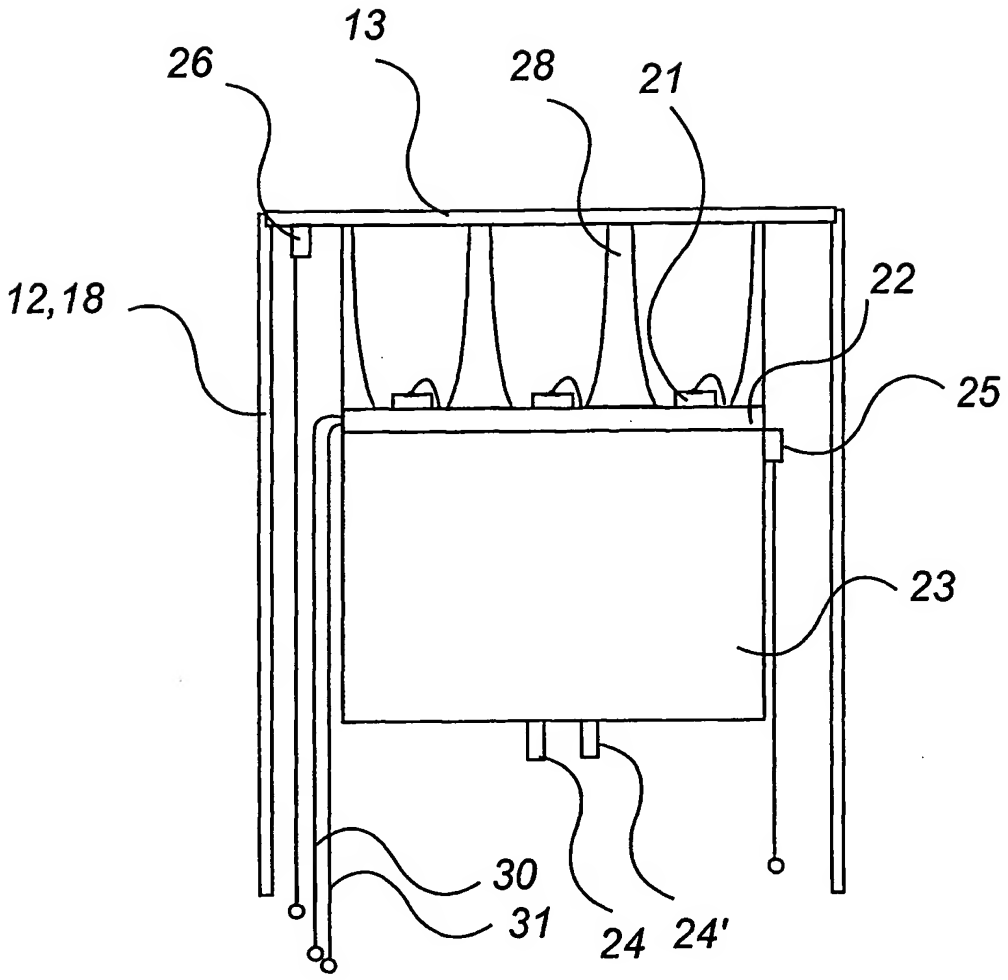

Fig.2

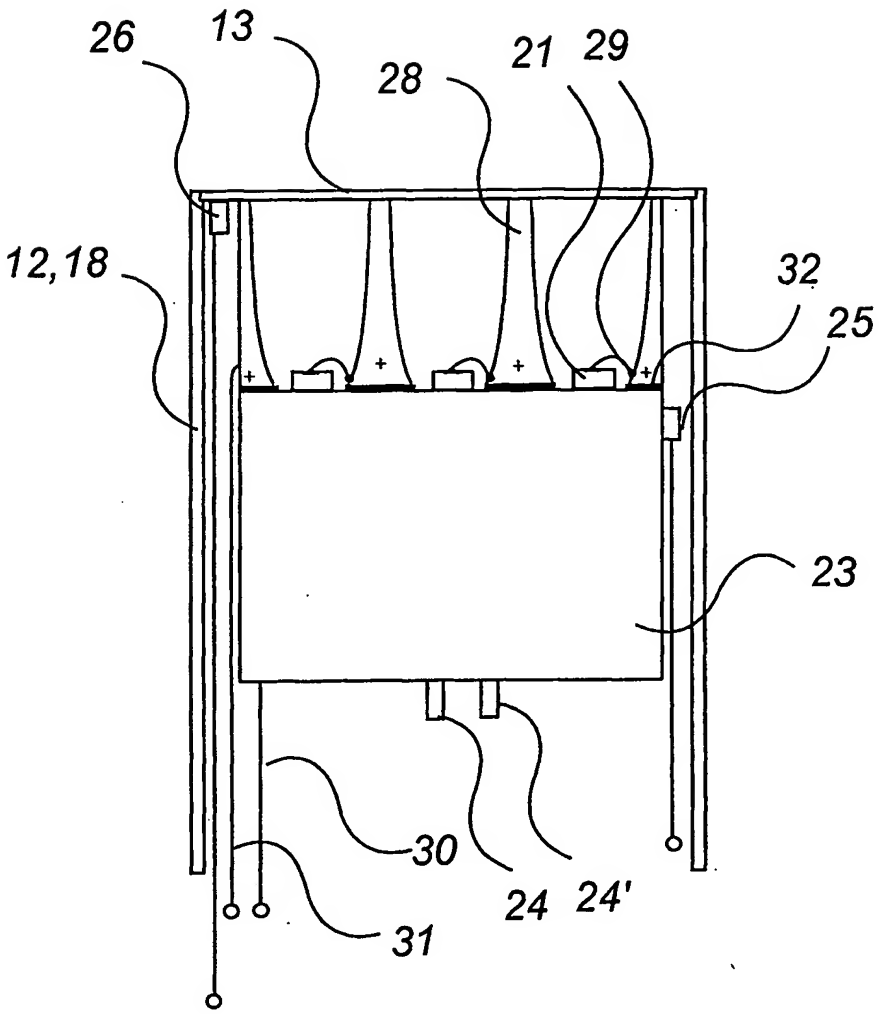

Fig.3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 02/00263

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: A61C 19/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: A61C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 0067048 A2 (PREMIER LASER SYSTEMS,INC.), 9 November 2000 (09.11.00), claims 1,8, abstract ---	1-19
A	WO 0013608 A1 (AKEDA DENTAL A/S), 16 March 2000 (16.03.00), abstract --- ---	1-19

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 June 2002	03 -07- 2002
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer JACK HEDLUND/BS Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

Information on patent family members

01/05/02

International application No.
PCT/FI 02/00263

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0067048 A2	09/11/00	AU 4698100 A	17/11/00
		EP 1180983 A	27/02/02
WO 0013608 A1	16/03/00	AU 5504299 A	27/03/00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI02/00263

Box I **Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 20-29
because they relate to subject matter not required to be searched by this Authority, namely:

See PCT Rule 39.1 (iv): Methods for treatment of the human or animal body by surgery or therapy, as well as diagnostic methods.

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II **Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.